



TEKTRONIX, INC.

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October

Service Scope

"the

state of the art

in sampling"

*committed to progress
in waveform measurement*

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T. Nelson, Systems Consultant 1/67
Box 1546
Poughkeepsie, N.Y. 12603

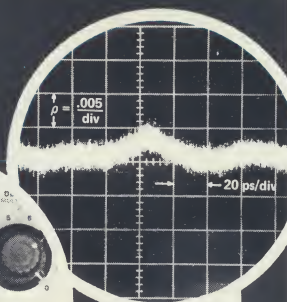


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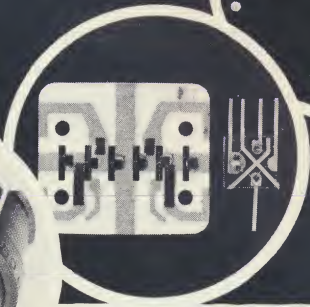
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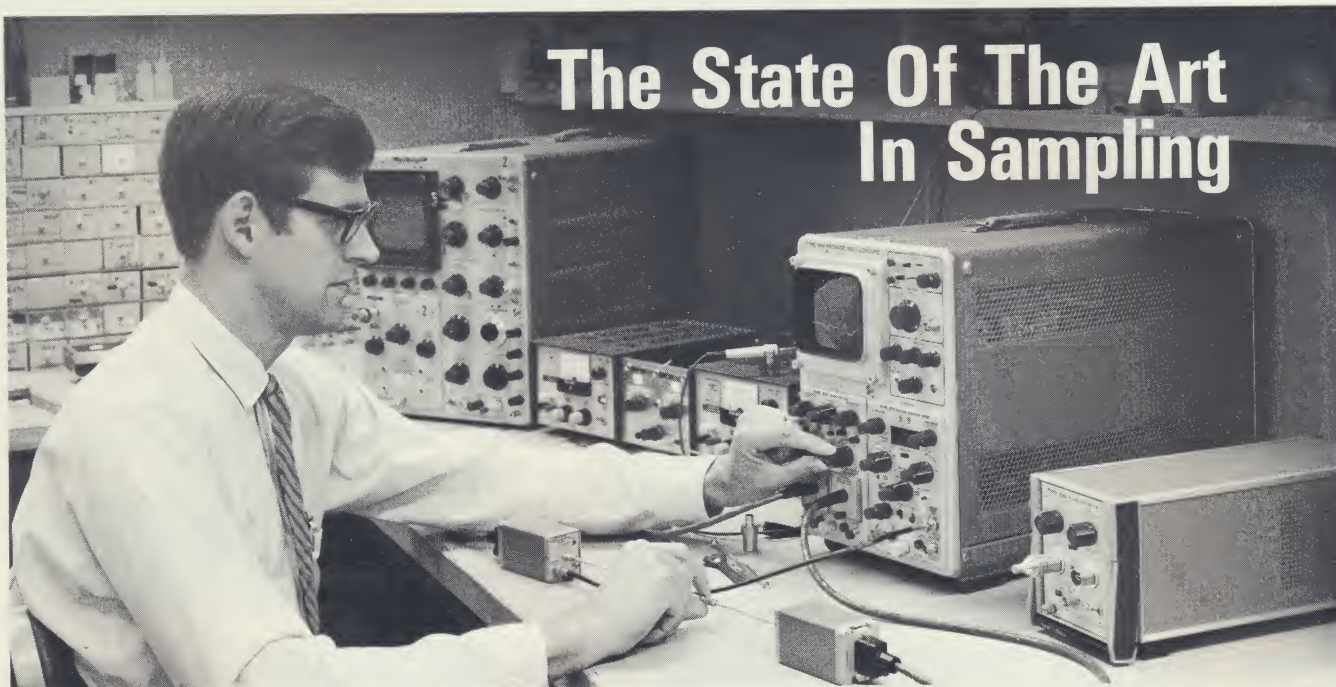
OCTOBER 1968

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The State Of The Art In Sampling

Al Zimmerman (Sampling and Digital Instruments) checks a connector pair with a high resolution in-line TDR setup. See fig 5b on page 5 for more details.

Development of a 25-ps (14 GHz) instrument, a line of "plug-in plug-ins", and realization of much of the potential of random sampling provide a new criterion for sampling measurements. These new developments in sampling circuitry and sampling packaging have combined to offer the user more versatility than ever before.

Al Zimmerman

Program Manager,
Sampling & Digital Instruments

COVER

Seven characteristics of state-of-the-art sampling are symbolized by samples of an oscilloscope display. From lower left: 3-mm connectors; Tektronix-developed devices (S-4 chip, S-3 chip); 25-ps digital readout; 3 sampling modes (random, sequential, and real-time sampling); the current line of Tektronix sampling heads; digital delay; and 35-ps risetime TDR.

The Type 3S2 Vertical Sampling Unit was announced at IEEE '68 with two plug-in heads—the Type S-1, 350-ps Sampling Head and the Type S-2, 50-ps Sampling Head. At WESCON '68, less than 6 months later, four more heads were introduced: the Type S-3, 350-ps high-impedance Sampling Head; the Type S-4, 25-ps Sampling Head; the Type S-50, 25-ps risetime Pulse Generator Head; and the Type S-51, 1-to-18 GHz Trigger Countdown Head. The latter two special-purpose heads are not capable of producing a display since they contain no sampling gate.

Concurrent with these sampling heads, the Type 285 Power Supply was designed to power the special-purpose plug-in heads in the event both vertical channels are required. Using these components, the user has a number of ways to combine the various heads for the most versatility from his sampling oscilloscope.

A sampling oscilloscope makes use of a great deal of relatively slow-speed signal processing circuitry. The input to the signal processing circuitry is an ideal choice to apply the plug-in idea. These miniature ($4\frac{1}{2} \times 1\frac{3}{4} \times 2$ inch) sampling heads contain all of the high-speed circuitry which normally make up the front end of a sampling oscilloscope. Use of plug-ins allows the sampling oscilloscope to adapt and interface with much more versatility to the numerous signal sources available.

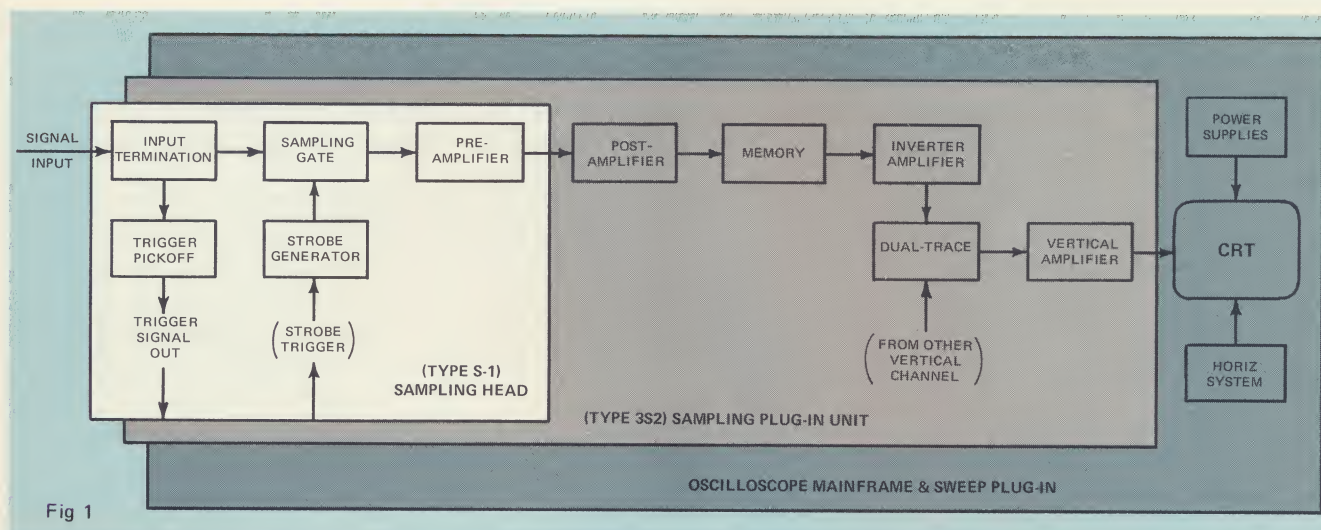


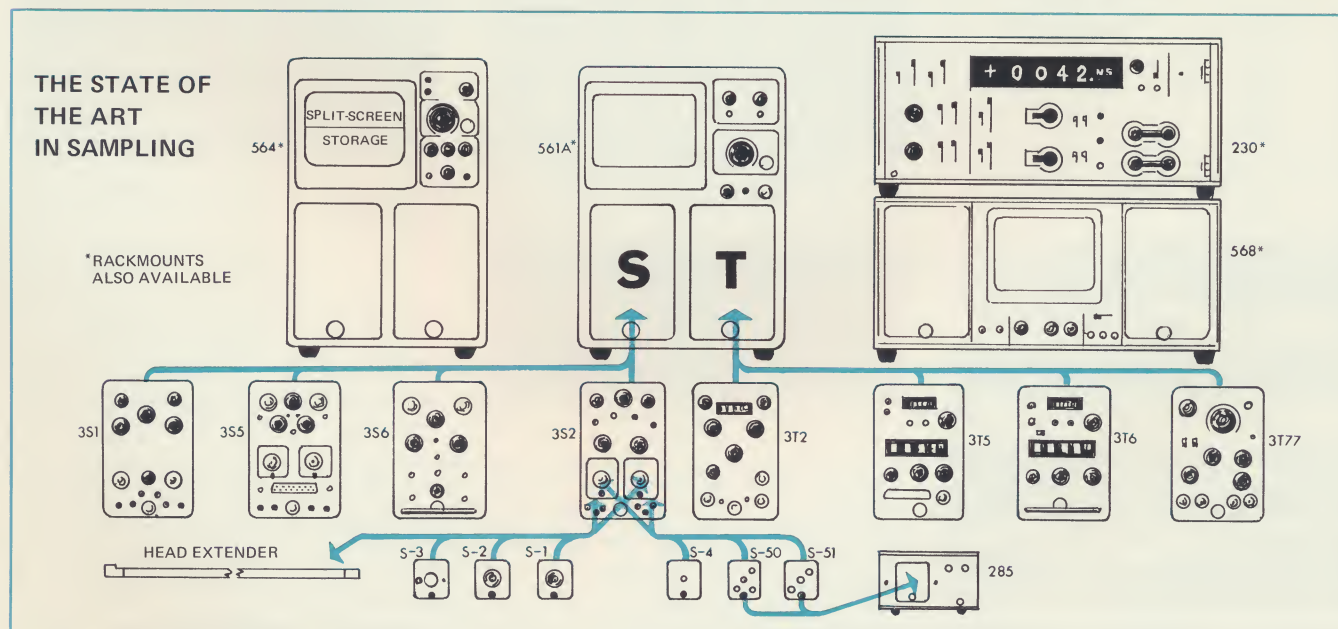
Fig 1

Prior to the sampling head development at Tektronix, a typical sampling unit occupied roughly 75% of its circuitry with the processing of slow speed signals (i.e. sampling-loop amplifiers, memories, dual-trace switching, and the main vertical). As a result, when changing from a 50- Ω general-purpose sampler to a high-impedance sampler, or to a higher speed 50- Ω sampler, nearly 75% of the sampler purchased was redundant circuitry. By creating a module which contains only those circuits which determine the input configurations, noise, sensitivity, and bandwidth of the sampler, these problems have been effectively solved with a degree of adaptability not possible before. This allows a wide range of operational characteristics by changing only the sampling head and *not* requiring the replacement of a complete plug-in vertical sampling unit.

Fig 1 shows how a typical sampling head relates func-

tionally to the rest of the oscilloscope. The nature and extent of the circuitry contained within the sampling head depends on whether it is intended for general purpose, low noise, high speed, 50 Ω , probe type, or other applications (i.e. trigger countdown or 25-ps pulse generator).

Because an individual sampling head represents a relatively small investment, both for the user and in terms of development cost for the manufacturer, there is more incentive to design heads and pursue additional performance trade-offs. The development costs of a sampling head are appreciably less than that of a complete vertical sampling unit. As a result, performance trade-offs may be pursued that were not economically feasible prior to the development of this concept. The table on page 4 shows some of the performance characteristics for the current line of sampling heads.



Sampling heads may either be plugged directly into the larger plug-in unit or may be used remotely at the end of a 3 or 6-foot extender cable. The ability to put the sampling head right at the measurement source allows dual-trace displays of signals originating at different locations—without interconnecting signal cables. Crosstalk between display channels is eliminated by the shielding afforded by completely separate sampling heads. The physical independence of the two channels further permits intermixing of head types so performance and input configuration may be matched to the particular measurement requirement. There is no longer the necessity of purchasing a dual-trace sampling unit if only a single-trace display is required.

Signal losses in the cables used to interconnect a system can also be eliminated by using sampling heads on extender cables. This practice can result in significant savings in signal level at frequencies above 5 GHz. For example, both RG8A/U and RG58A/U have losses of well over 1 dB/ft at 10 GHz.

Fig 3 dramatically illustrates the loss in amplitude when a 3-ft coaxial cable transmits a 15-GHz signal.

Such losses are minimized by using extender cables and physically placing the individual head adjacent to its source.

Type S-1 Clean Response/Low Noise

The Type S-1 Sampling Head offers excellent transient response, low-noise characteristics, 50- Ω input impedance, and low cost. The Type 284 Pulse Generator and the Type 3S2/S-1 provide the cleanest 350-ps response currently available. Its transient response is specified as +0.5%, -3% or less for 5 ns after transition; $\pm 0.5\%$ after 5 ns (with Type 284 Pulse Generator).

Type S-2 High Speed/Low Cost

The Type S-2 Sampling Head is a 50- Ω , 50-ps risetime unit with 7-GHz equivalent bandwidth. In this unit, the design compromise is faster risetime (at the expense of noise and transient response) for an "economical" price. Unsmoothed noise is 6 mV and the transient response is $\pm 5\%$ for the first 2.5 ns and $\pm 2\%$ thereafter (with Type 284 Pulse Generator).

SAMPLING HEADS							
Type	Risetime	Equivalent Bandwidth	Trigger Pick-Off	Noise (Unsmoothed)	Input Z	Input Connector	Price
S-1	350 ps	1 GHz	Yes	2 mV	50Ω	GR874	\$250
S-2	50 ps	7 GHz	Yes	6 mV	50Ω	GR874	\$300
S-3	350 ps	1 GHz	No	3 mV	100 kΩ 2.3 pF	Probe	\$375
S-4	25 ps	14 GHz	Yes	10 mV	50Ω	3 mm	\$750
NON-SAMPLING HEADS							
Type	Description				Output Connector		Price
S-50	25-ps risetime, tunnel-diode pulse generator				3 mm		\$450
S-51	1-18 GHz trigger countdown				3 mm		\$425
PLUG-IN VERTICAL UNITS							
Type	Remotely Programmable	Physical Configuration	Program Connector	Adjustable Inter-channel Delay	Real Time Sampling	Price	
3S1	No	Non Plug-In	None	No	Yes	\$1150	
3S2	No	Plug-In	None	Yes	Yes	\$ 800	
3S5	Yes	Plug-In	Front	Yes	Yes	\$1450	
3S6	Yes	Remote	Rear	Yes	Yes	\$1450	
PLUG-IN HORIZONTAL UNITS							
Type	Type of Sampling	Sweep Delay			Remotely Programmable	Jitter	Price
3T2	Random, Sequential	Up to 5 cm on any time/div			No	30 ps	\$ 990
3T5	Sequential, Real Time	999.9 ns in 100-ps increments			Digital	Yes	\$1550
		9.999 μs in 1-ns increments					
3T6	Sequential, Real Time	999.9 μs in 100-ns increments				Yes	30 ps
3T77A	Sequential Only	Min 100 div/variable			No	50 ps	\$ 690
OSCILLOSCOPE MAIN FRAMES							
Type	Storage			Digital Readout			Price
561A	No			No			\$ 530
RM561A	No			No			\$ 580
564	Yes			No			\$ 925
RM564	Yes			No			\$1025
567	No			Yes			\$ 750
RM567	No			Yes			\$ 850
568	No			Yes			\$ 875
RM568	No			Yes			\$ 925

Type S-3 High-Impedance Sampling Probe

The Type S-3 Sampling Head employs a unique design approach for an active sampling probe. A 50-k Ω resistor provides two times attenuation and is designed as an integral portion of the probe. The first stage of the sampling preamplifier (an FET stage) is physically located in the probe itself. These improvements result in a larger voltage signal from the sampler with an improved signal-to-noise ratio.

A portion of this improvement is traded off for other advantages. This approach, however, still has four major advantages. (1) More rugged mechanically. Screw-on attenuators. (2) More rugged electrically. The 50-k Ω series resistance limits the current for diode protection. 100 V DC may be applied to the probe tip. (3) Since the source impedance is isolated by the 50-k Ω resistor, varying the source impedance has much less effect on the sampling bridge than conventional sampling probe designs. (4) The built-in attenuator automatically reduces any kickout that the balanced bridge may still have.

Type S-4 25-ps State Of The Art

The Type S-4 provides state-of-the-art sampling performance with its 25-ps, 14-GHz performance. This unit introduces the first use of a 3-mm (mates with OSM[®])[†] connector used on an oscilloscope. The Type S-4 is specified with less than 10 mV of noise (un-

smoothed) and a $\pm 10\%$ transient response as observed with the S-50 25-ps risetime Pulse Generator. Fig. 5 illustrates the Type S-4 Sampling Head and the Type S-50 Pulse Generator Head used in a Type 3S2 for a high-resolution TDR measurement.

The user is assured of more sampling head types evolving because of the relatively low development cost associated with the head. In addition, development times are shorter since only the input characteristics are being changed. These two factors, combined with the development of new devices, offer promise of an even wider line of performance trade-offs in the future. With each advance in measurement technology, new heads can be added quickly to extend performance or convenience features. The current family of existing sampling heads is an excellent example of the speed with which these new heads may be developed.

Random Sampling Eliminates Need For Signal Delay Lines

The introduction of the 3T2 Random Sampling Sweep Unit in 1967 provided the impetus to develop the sampling head concept. Prior to this time, sampling oscilloscopes offering internal triggering used trigger pick-off circuitry and delay lines to develop the necessary pre-trigger. Two compromises were involved: (1) There was always some signal degradation since the signal passed through the delay line element; and (2) input

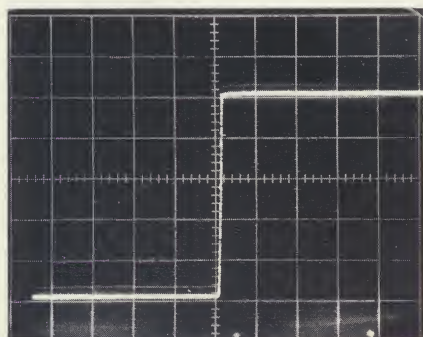


Fig 2. Transient response of Type S-1 and Type 284. Vert: 50 mV/cm. Horiz: 2 ns/cm.

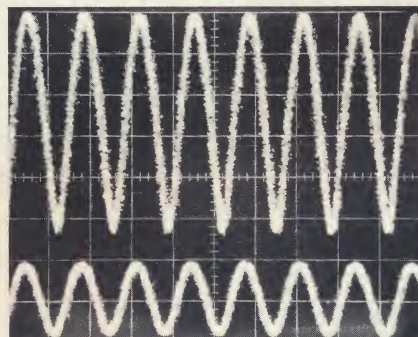


Fig 3. Signal loss due to 3-foot coaxial cable at 15 GHz. Vert: 100 mV/cm. Horiz: 50 ps/cm.

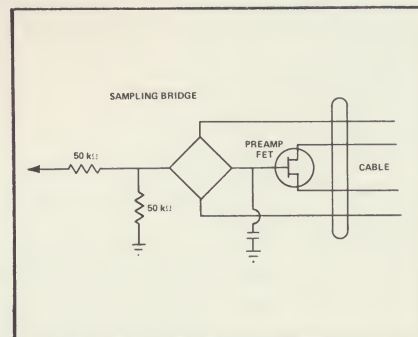


Fig 4. Type S-3 Sampling Head.

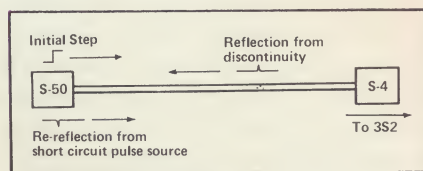


Fig 5a. In-line TDR system.

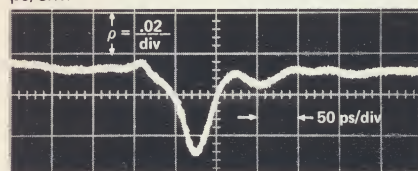


Fig 5b. Discontinuity from connector pair.

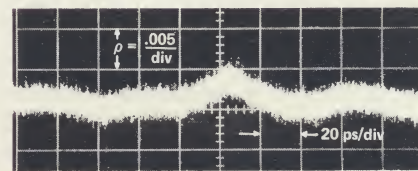


Fig 5c. Maximum amplitude resolution.

Fig 5. The in-line TDR system is particularly well-suited for studying discontinuities in short, high-quality transmission systems. The Type S-50 Pulse Generator propagates the pulse down the test line until it encounters the point discontinuity which reflects energy to the generator. The short circuit source impedance (3 Ω) of the TD generator re-reflects the energy back through the test line into the sampler for observation. Signal-to-noise considerations are optimized since the full 400 mV of the pulse is available. Fig 5c shows an observed ρ (reflection coefficient) of 0.004 which corresponds to a shunt capacitance of 0.008 pF. Fig 5d shows two discontinuities separated in time by 40 ps (80 ps displayed) or a distance of 8.4 mm in a solid Teflon* transmission line.

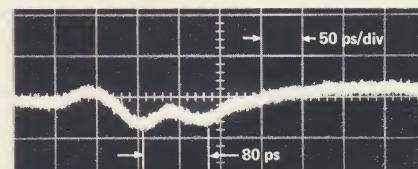


Fig 5d. 40-ps time resolution.

[†] Registered trademark of Omni Spectra, Inc.

* Registered trademark of DuPont

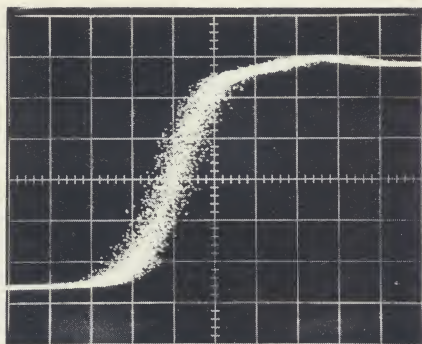


Fig 6. Type S-4 and Type S-50, 35 ps displayed risetime. Vert: 100 mV/cm. Horiz: 20 ps/cm.

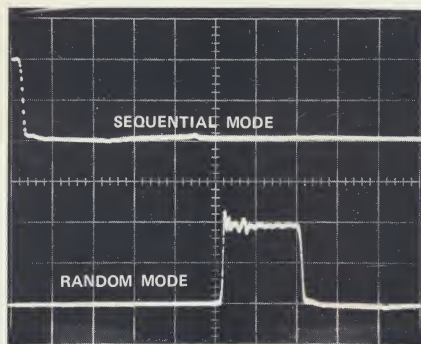


Fig 7. Multiple Exposure. The random mode allows observation of the leading edge without delay lines or pretriggers. Vert: 100 mV/cm. Horiz: 10 ns/cm.

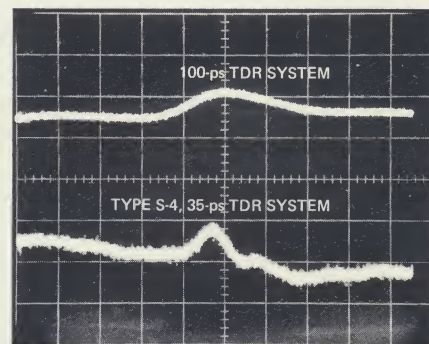


Fig 8. Multiple exposure of 100-ps and 35-ps TDR systems. Vert: 5% ($\rho = 0.05$)/cm. Horiz: 50-ps/cm.

impedance levels were restricted to a low impedance transmission-line approach since high-impedance delay lines are impractical. As a result, when using 100-k Ω sampling probes, there was no means of internal triggering. In addition, sampling oscilloscopes with rise-times faster than ≈ 350 ps did not offer internal triggering because of the absence of the signal delay line.

The availability of the Type 3T2 Random Sampling Sweep Unit has eliminated these restrictions. Its unique random-sampling circuitry *always* allows observation of points *prior to the triggering transition itself*. Depending on the sweep rate of the display, microseconds, or even milliseconds of time prior to the triggering event can be observed! This is an amount far greater than any conventional real-time oscilloscope can provide. With high-impedance probes, the advantages of internal triggering are present (although a separate trigger probe is required) since the user can monitor points in time before the trigger occurs. At the same time, it is possible to view 25-ps signals with the Type S-4 Sampling Head without pretriggers.

The development of the Type 3T2 Random Sampling Sweep Unit was a major factor in initiating development of the plug-in head concept. Once random sampling had been developed, it was *then* possible to consider a modular design approach without the use of delay lines, and still provide the advantages that internal triggering offers. Eliminating signal delay lines removed a major system bandwidth limitation and contributed markedly to size and weight reductions. At the same time, the problem of aberrations due to skin effect, dielectric losses of the delay lines, and compensation circuits were automatically eliminated.

Variable Interchannel Delay

Variable interchannel delay is a feature of the Type 3S2 Plug-In that has not before been available. The

user now has the ability to vary the delay of one channel, ± 5 ns, to ensure exact coincidence of time relationships. Minor manufacturing tolerances, probe differences, signal paths, transmission lines, etc., may now be exactly matched to allow more precise time comparisons.

This feature is of particular value when a high-impedance sampling head and a 50- Ω sampling head are used together (cable transit times are different), or when different length extender cables are required. In addition, it ensures optimum X-Y displays when the sampler is used in the A vertical, B horizontal mode.

Digital Sweep Delay

The development of digital delay in a sampling time-base unit, Type 3T5/3T6, offers a new versatility for oscilloscope users. It is now possible to dial in an exact delay over the range of 100 ps—999.9 μ s (see fig 10). This delay is generated by incorporating a clock and digital counter to ensure a precise jitter-free display whose stability is not a function of the delay time. This technique allows the Type 3T5/3T6 to maintain its basic 30-ps jitter specification with delays of up to 1 μ s.

Programmable Sampling Units

The availability of the Type 3S5 and Type 3S6 Programmable Sampling Units provide a new capability for use with the Type 568/230 Digital Readout System. Plug-in sampling heads present maximum interfacing flexibility when signal sources require a different sampling head. The systems user is assured of maintaining maximum versatility since the systems limitation is basically determined by the sampling head characteristics.

The Type 3S5 and Type 3S6 offer digitally programmable control of deflection factor, DC offset, polarity, and smoothing. 27 program lines using negative logic (true = ground or < 2 V — false = open or > 6 V) are required to program all measurement functions.

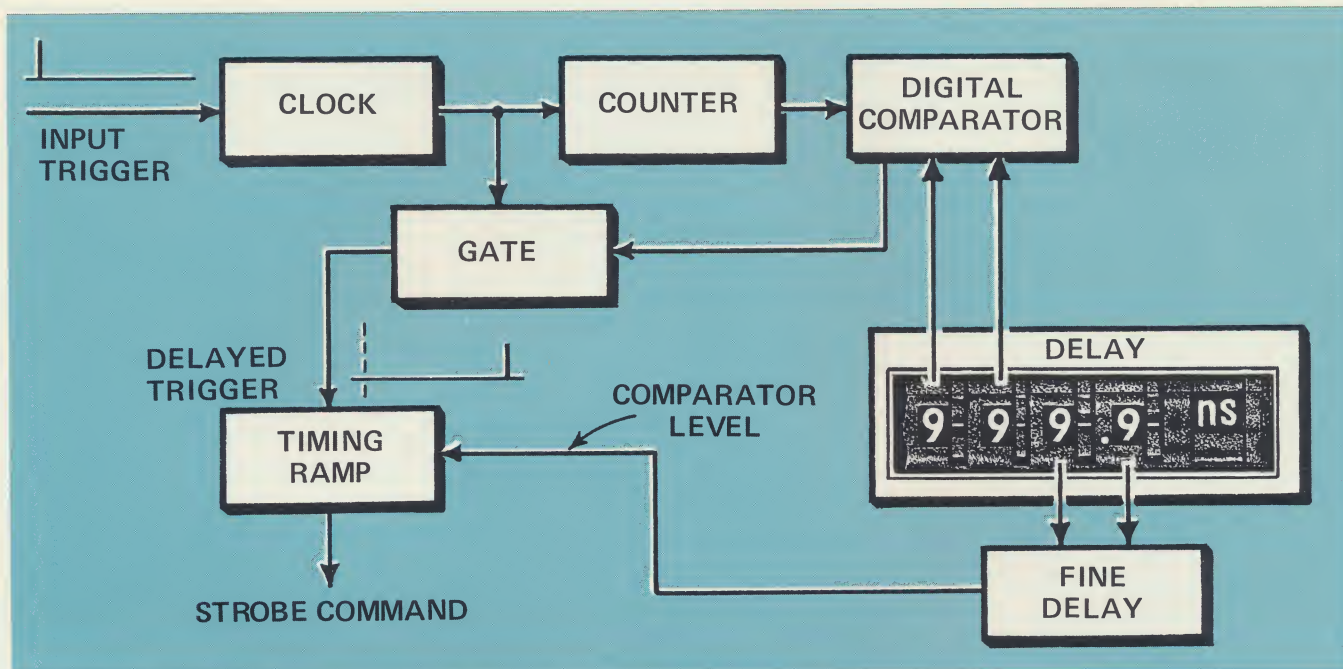


Fig 9. Simplified block diagram of digital delay circuitry.

DIGITAL DELAY RANGE		
Delay Range	Increments	Time/Div
999.9 ns	100-ps	100 ps/div to 500 ps/div
9.999 μ s	1-ns	1 ns/div to 1 μ s/div
999.9 μ s	100-ns	2 μ s/div to 500 μ s/div

Fig 10.

The Type 3S5 and Type 3S6 have identical electrical characteristics. The Type 3S6 has all connections, including remote sampling heads on the rear panel, while the Type 3S5 provides all connectors on the front panel.

The Type 3T5 and Type 3T6 Programmable Sampling Sweep Units provide a wide range of digitally programmed functions. Time/div, delay time, and samples/sweep are remotely programmable (true = ground or $< 2\text{ V}$ - false = open or $> 6\text{ V}$), or controllable from the front panel. The units are programmable over the wide range of 100 ps/div to 500 ms/div in 30 calibrated steps. Real-time sampling is used over the range of 1 ms/div to 500 ms/div.

A new automatic trigger mode has been included in the Type 3T5 and Type 3T6 to eliminate the need for trigger adjustments as trigger amplitudes, repetition rates, risetimes, and pulse widths vary.

The Type 3T5 and Type 3T6 have identical electrical characteristics. The Type 3T5 has a program connector

and trigger input on the front panel while the Type 3T6 provides these connectors on the rear panel.

Real-Time Sampling

The Type 3S2 can provide 100 kHz pulses to each sampling head independent of the real-time time base unit. When the Vertical Sampling Unit is switched to the non-sampling position and a conventional time base unit inserted, real-time internal triggering is available. The real-time sampling mode is limited to approximately .1 ms/div since faster sweeps will begin to make the 10 μ s clock segments objectionable. Thus, signals exceeding 20 kHz are seldom viewed in this mode.

Real-time Sampling offers slower sweep rates with the full bandwidth of plug-in sampling heads. The characteristics of interest this mode offers are:

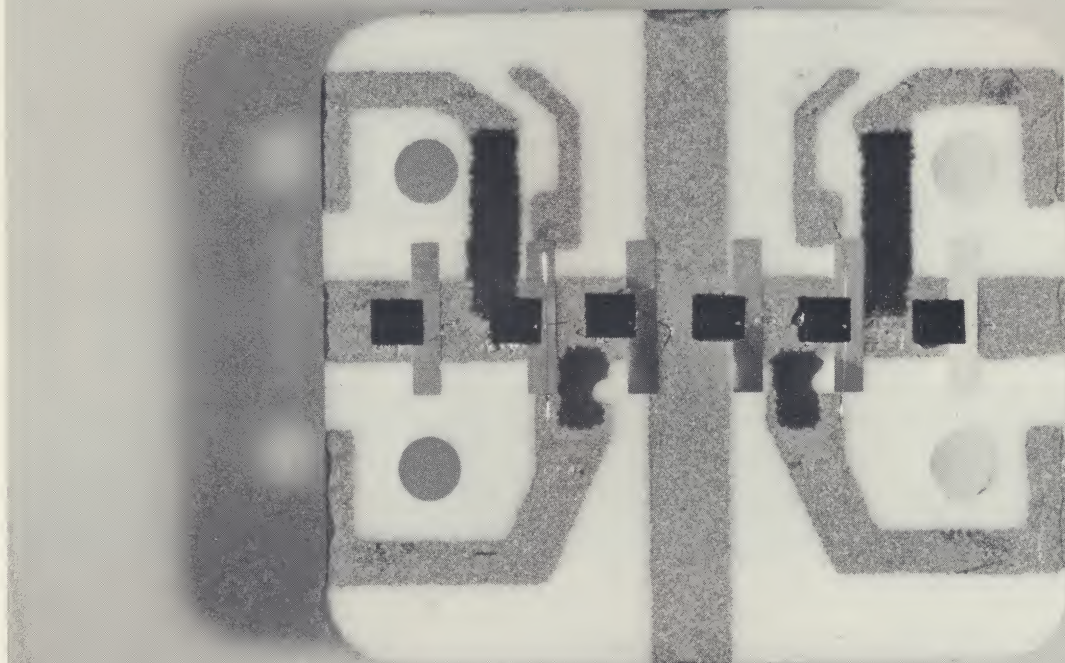
- (1) Slow sweeps with full bandwidth
- (2) Reduction of random noise through smoothing
- (3) DC offset capability with excellent overload recovery

Conclusion

The sampling head concept has brought a shift in design effort toward the front end of the sampler, where it really belongs. In addition, there has been a reduction in the total number of sampling plug-in units required for the designer to be attentive to the instrumentation needs of tomorrow.

These developments, combined with the options of digital readout, high resolution low-cost storage, random sampling and programmable units, offer the user more versatility at lower cost than ever before.

A New Approach to Fast Gate Design



A unique sampling gate eliminates risetime dependency upon strobe width. This new development offers the highest speed sampling system to date and offers promise for even faster gates.

George Frye
Project Engineer, Sampling

Fig 1 shows a section of delay line with switches inserted at point A and point C. A nonloading voltmeter placed at point B, measures the average of the voltage between the switches when the switch section is opened. When a fast step is applied to the line and the switches then opened, the following observations may be made.

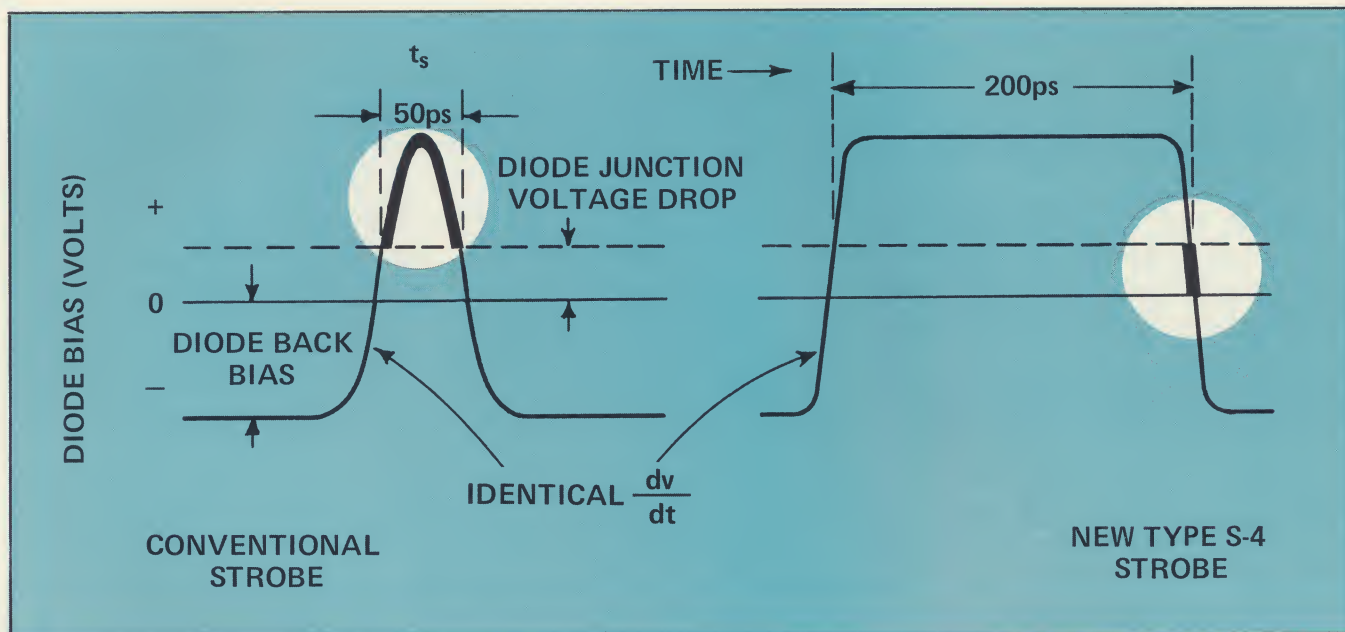
If the step propagating down the line is at point A when the switch opens, 0 volts are observed. If the switches are reclosed and a second observation made at a later time, when the wavefront has reached point C, the voltage is 1. When the step is just entering the switch at point A, we observe 0; if it is just leaving the switch at point C, we observe 1. Thus, we may state that the system 0-100% risetime is determined by the length of the switch section or C-A. Since we know the line has capacitance and voltage, we have effectively "trapped" a quantity of charge ($Q=CE$). If we now apply this concept to the model shown in fig 2, we can note some very important observations.

The model in fig 2 illustrates a simplified form of the

new sampling gate used in the Tektronix Type S-4 Sampling Head. Diodes replace the switches and instead of opening the switches simultaneously, we turn the diodes off one after another. Although it is a balanced system, only one half of the system will be described.

The leading edge of the strobe pulse turns the diodes on and the signal propagates into the conducting diodes and transmission line. The diodes remain on for the duration of the strobe pulse, being turned off by the trailing edge of the wave shape. The strobe pulse is designed to be longer than the transit time between the diodes.

Gate action begins when the strobe trailing edge turns D2 off. At the same time, suppose a signal front enters through conducting diode D1. When the front reaches D2, it is off since the strobe arrived there prior to the front. The signal front reflects and reaches D1 which is now off since the strobe trailing edge has preceded the front. Thus, the signal front has been effectively trapped in the transmission line between the two diodes. Note, however, that the gate characteristics are determined by the strobe trailing edge (only one transition).



The conventional sampling gate must take the diode from a fully-off condition, turn it fully-on, and return it to a fully-off condition. The time between the two fully-off conditions, t_s , is the strobe width and determines the risetime of the system. In the Type S-4 gate, the diodes are fully-on as gate action begins, and only one transition is needed. Risetime is determined by the length of the transmission line as pointed out in the text. The conventional strobe for a fast sampling gate is very narrow since the strobe width determines the system risetime. The Type S-4 uses a wide strobe and minimizes the problems inherent in narrow strobe generators.

In this system, the 0-100% risetime is determined by twice the propagation time between D1 and D2, since both the front and the strobe must traverse the distance.

The important points to note are the following: (1) Only one transition is required for the gate action (gate action occurs from a fully-on diode condition to a fully-off condition). Using one transition offers substantial noise reduction possibilities. (2) The risetime of the system is not dependent upon the strobe width. (3) The propagation time between diodes in this system (8 ps) is much less than the strobe period of approximately 200 ps. (4) Because the diodes currently used may be turned off in 5-10 ps, they do not present a significant risetime limitation.

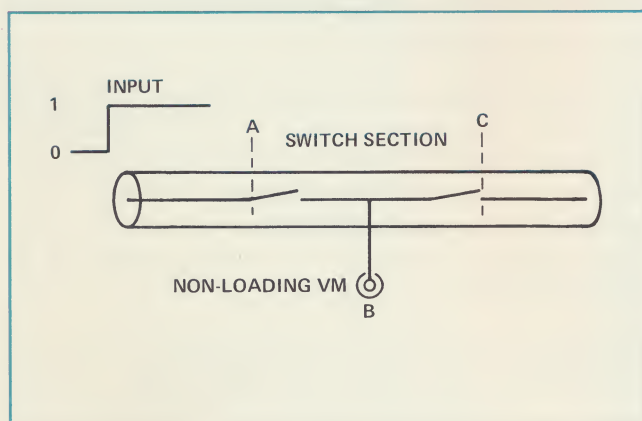


Fig 1. Delay-line section.

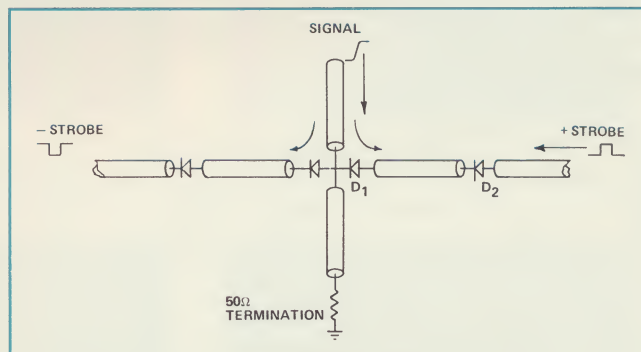


Fig 2. Simplified model of sampling gate for Type S-4.

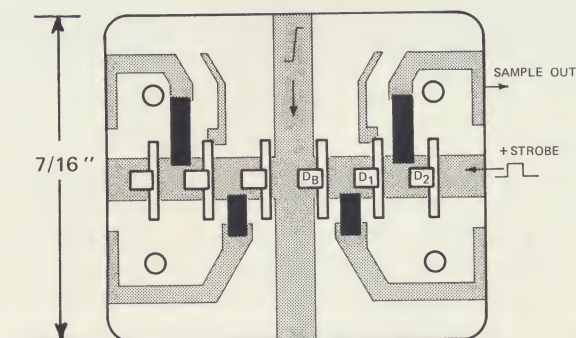
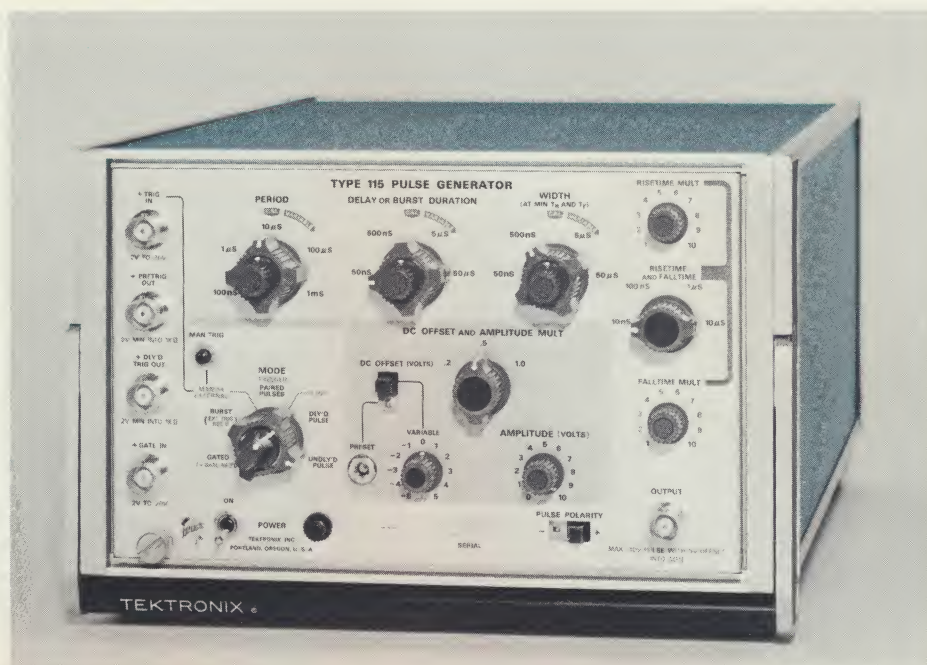


Fig 3. 25-ps hybrid gate. 6 Tektronix-manufactured diode chips are placed on a ceramic substrate. The substrate is formed with slots (0.020) which remove high dielectric constant material near the diodes to reduce shunt capacitance. The diode chips are set in place, extending over the slots, to minimize lead inductance. DB is in the circuit to correct for signals capacitively coupled through the gate diodes when they are not conducting (blowby).

A Wide Choice of Pulses

Jerry Shannon
Project Manager,
Generators



Tektronix' entry into the medium price general-purpose pulse generator market sets new performance standards, including total peak-to-peak aberrations of less than 3%.

The Type 115 Pulse Generator was designed to meet the continuing requirement for a "clean" pulse generator in the mid-frequency range (100 Hz — 10 MHz). By providing separately variable amplitude, width, period, DC offset, risetime, falltime, and delay functions, the Type 115 offers a wide choice of stable pulse characteristics.

The aberrations of the Type 115 are specified at +3%, -3%, total 3% peak-to-peak. Fig 3, on page 11, illustrates a magnified view of the baseline and pulse top of both positive and negative pulses with each division representing 2% of P-P amplitude. Note, all aberrations are well within the 3% specification.

The Type 115 has variable risetimes and falltimes (10 ns-100 μ s) which remain constant while varying pulse amplitude. The amplitude may be varied from ± 10 V (50 Ω) to ± 100 mV without changing the risetime or falltime from its 5% ± 1 ns accuracy specification. In addition, the full range of \pm DC offset is available to the user. A screwdriver preset is located on the front panel to allow DC voltage offset to be preset. A front panel switch offers the choice of variable or preset DC offset.

Considerable attention is given to front panel logic in the Type 115. An example is in the use of the term

pulse period instead of pulse repetition rate to be more consistent with time-domain logic. This also helps the user to more quickly determine an error in setup (i.e. width greater than period).

A unique burst mode provides output pulses as shown in fig 9. In this position, the delay control functions as a BURST DURATION control while the PERIOD control determines pulse repetition rate. This mode is convenient since only an external trigger is required to initiate the burst (gate waveshape is not required).

The Type 115 is a solid-state design which ensures optimum reliability and includes a short-proof power supply. Plug-in transistors have been used throughout with the exception of high power transistors that require the chassis as a heat sink. Output protection is a feature of the Type 115 and the output may be subjected to open, short, or inductive surges without damage to the instrument.

The Type 115 has been designed to occupy one-half of a standard 19-inch rack. Two Type 115 Pulse Generators require only 5 $\frac{1}{4}$ inches of panel height when used with an optional rack adapter. Thus, the Type 115 is ideally suited for applications where space is at a premium, whether a portion of a complex system, or in bench operation.

The price of the Type 115 Pulse Generator, including a 5-watt 50- Ω termination and cable, is \$825. Further details are included on pages 15-16 in the New Product Supplement to Tektronix Catalog 27 (1968).

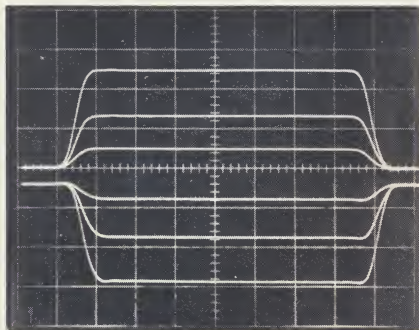


Fig 1. Multiple exposure showing typical aberrations on positive and negative pulses with varying amplitudes. Horiz: 20 ns/cm. Vert: 4 V/cm.

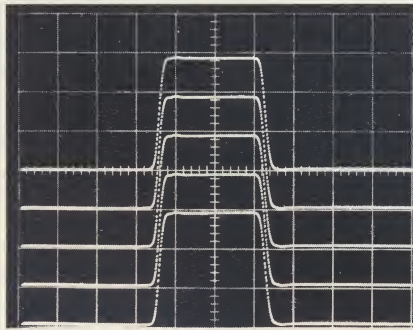


Fig 2. Multiple exposure, 7 V pulse with 10 ns rise and fall showing offset capability of ± 5 V in 2.5 V increments. Horiz: 50 ns/cm. Vert: 2.5 V/cm.

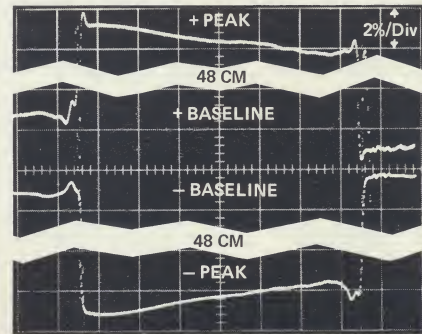


Fig 3. Composite photo illustrates + and -10 V pulses (t_r and t_f 10 ns) with waveform top and baseline each magnified 50 times. Note that all aberrations are well within 3%. Horiz: 2 ns/cm. Vert: 200 mV/cm.

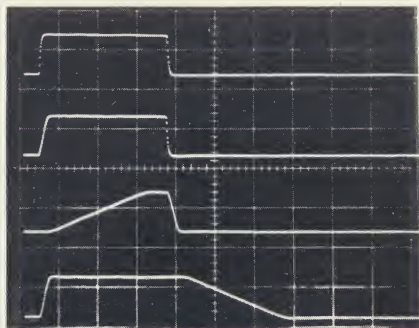


Fig 4. Multiple exposure showing variable risetime and falltime. Horiz: 500 ns/cm. Vert: 10 V/cm.

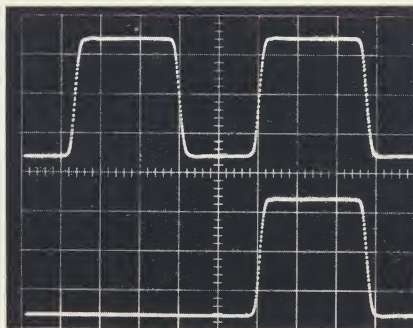


Fig 5. Multiple exposure illustrating PAIRED PULSES (upper) and DELAYED PULSE (lower) modes. Horiz: 50 ns/cm. Vert: 25 V/cm.

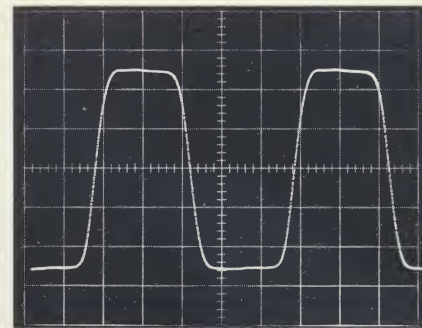


Fig 6. Minimum pulse separation. Horiz: 20 ns/cm. Vert: 2 V/cm.

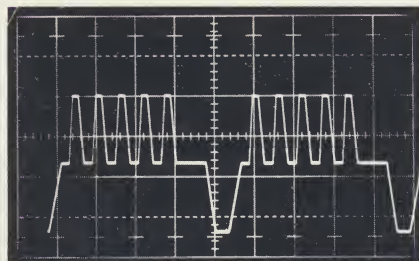


Fig 7. Pulse burst from combined output of two Type 115's. The burst of pulses was triggered by the + delayed trigger from the instrument generating the pedestal. Horiz: 10 μ s/cm. Vert: 2 V/cm.

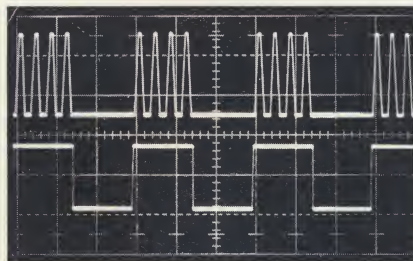


Fig 8. GATED mode. Multiple exposure showing time relationship between external gate input (lower trace) and pulse burst. Horiz: 5 μ s/cm. Vert: 5 V/cm.

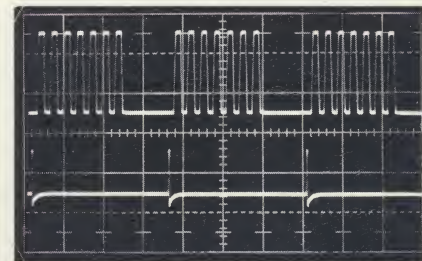


Fig 9. BURST mode. Multiple exposure showing time relationship between external trigger (lower trace) and pulse burst. Horiz: 1 μ s/cm. Vert: 5 V/cm.

MIXING PULSE SOURCES

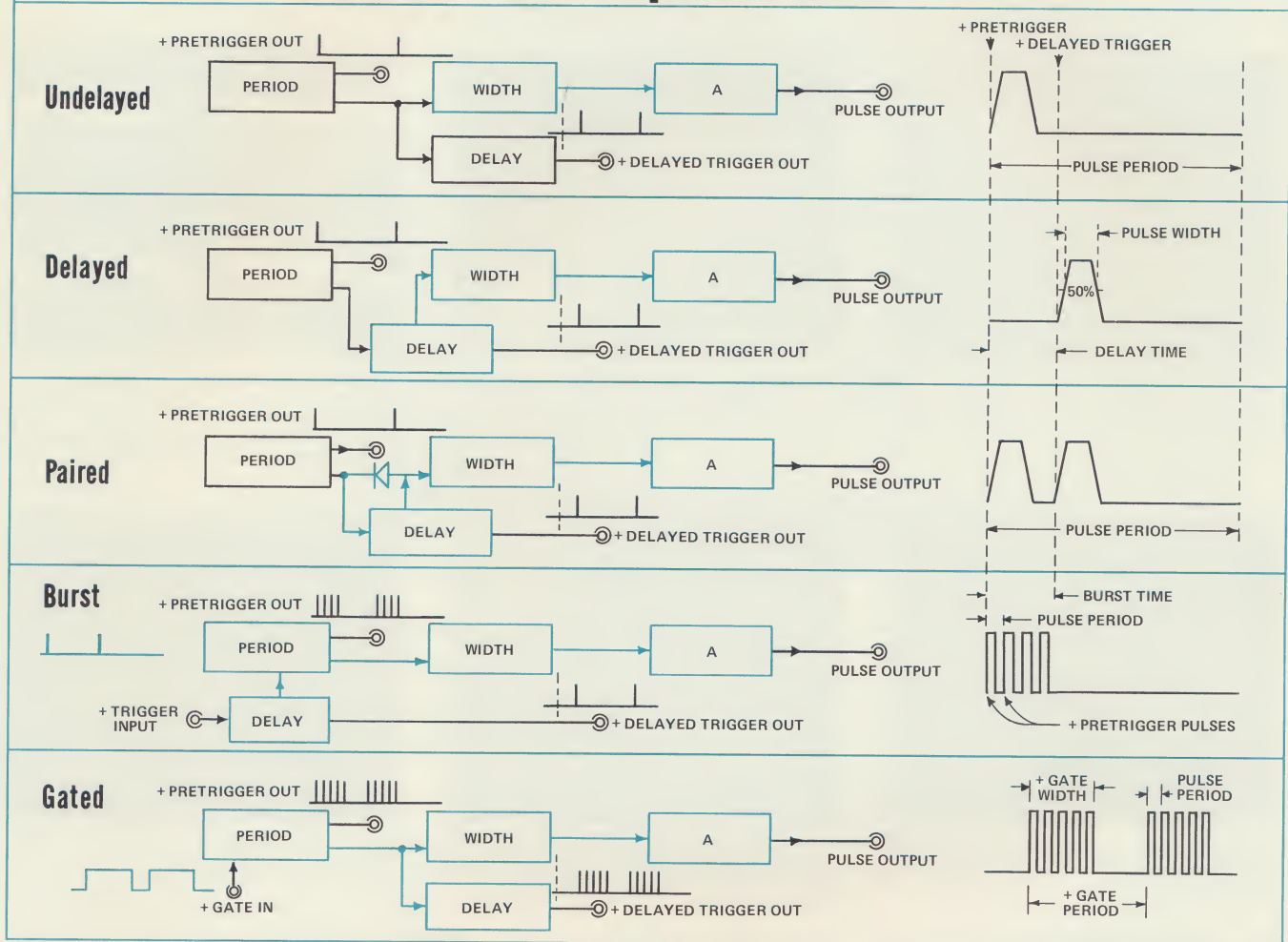
Often it is necessary to mix two or more pulse generators to obtain a desired pulse train. Fig 7 shows one complex waveshape that may be obtained by mixing two Type 115 pulse generators. Three simple rules will minimize problems when mixing sources.

- (1) Do not exceed the output voltage specification

with the combination of pulse amplitude and offset. (Type 115 specification ± 10 V pulse ± 5 V DC offset.)

- (2) Use .5 multiplier to avoid exceeding the output voltage specification when mixing two generators.
- (3) Use multiplier of .5 or .2 (provides back termination) or a power divider to minimize reflections. (Only important with fast risetimes.)

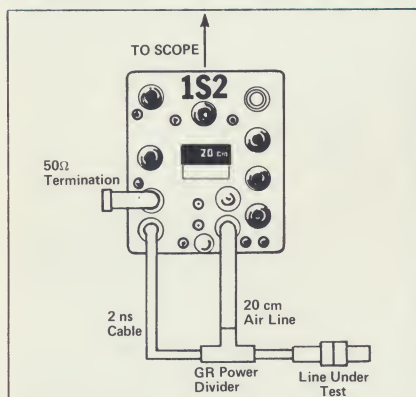
Modes of Operation



TYPE 115 PULSE GENERATOR CHARACTERISTICS

FEATURE	RANGE	GENERAL APPLICATION
AMPLITUDE DC OFFSET	± 10 V to ± 100 mV, 3 ranges continually variable ± 5 V in 3 ranges continually variable — full range useable with any amplitude setting	Threshold determination stimulation, linearity Baseline compatible with input requirements
RISETIME AND FALLTIME WIDTH	10 ns - 100 μ s in 4 ranges continually variable 50 ns to 500 μ s in 4 ranges continually variable (duty factor at least 75%)	Transient response testing Duty cycle appropriate for system response
DELAY PERIOD	50 ns to 500 μ s in 4 ranges continually variable 100 ns to 10 ms in 5 ranges continually variable (minimum pulse separation -50 ns)	Time-domain control of event Frequency of event (clock rate)
GATED BURST	Ext positive pulse required, 2 to 20 V Ext positive trigger required, 2 to 20 V	Generation of pulses coincident with gate duration Generation of pulses during BURST DURATION initiated by ext trigger
PAIRED PULSES EXTERNAL TRIGGERING SINGLE PULSE MIXING	Separated by delay time, recur each period Ext positive trigger required, 2 to 20 V Manual push button See mixing sources on page 11	Resolution between events Method of external time reference Single-event occurrence Algebraic sum of two pulse generators — more complex waveshapes possible
TRIGGER OUTPUTS	+Pretrigger +2 V into 1 k Ω , +Delayed Trigger +2 V into 1 k Ω	Initiate remote timing functions
ABERRATIONS	+3%, -3%, 3% peak-to-peak	More accurate determination of system response

Service Notes



OPTIMIZING SYSTEM RISETIME

The system risetime of a 1S2 may be improved from 140 ps to about 100 ps by a rather simple technique, if you can tolerate a 4-to-1 increase in signal-to-noise ratio. Noise is usually a problem only when trying to see extremely low percentage reflections, and the additional time resolution may be useful in other applications. Rho calibration will also be off by a factor of four.

1. Connect a 20 cm GR air line (017-0084-00) to the $\frac{1}{4}$ volt step output.
2. Attach a GR power divider (017-

0082-00) to the end of the air line.

3. Attach the cable or transmission line to be tested to one branch of the power divider.
4. Attach a short length of high quality cable between the other branch of the GR power divider and one input to the 1S2. (Tektronix 2 ns cable, 017-0505-00, can be used with surprisingly little deterioration of response.)
5. Attach a 50-ohm termination (017-0081-00) to the other 1S2 input. That's all there is to it.

USED INSTRUMENTS FOR SALE

1—Type 575 Transistor Curve Tracer. In good condition. Contact: Howard Mappen, Molded Electronics, Inc., 459 East Main Street, Denville, New Jersey 07834. Telephone: (201) 625-0299.

1—Type 524AD, SN 2710, and one Cathode Follower Probe. Contact: Mr. Schatz, Bond TV, Hudson Boulevard, Jersey City, New Jersey. Telephone: (201) 333-3112, day; 434-6574, night.

1—Type 570, SN 5508. Price: \$500. In excellent condition. Contact: Guy Falcioni, Air Reduction Research Labs, Murray Hill, New Jersey 07975. Telephone: (201) 464-2400, ext. 283.

1—Type 533A/535/541/545. Also, 2—preamps and complete 160-Series Generators. Contact: H. Posner, Pacific Combustion Engineering Company, 5272 East Valley Blvd., Los Angeles, California. Telephone: (213) 225-6191.

1—Type 560, SN 000358. 1—Type 50, SN 000250. 1—Type 51, SN 000268. Contact: Bob Long, Bank Administration Institute, 303 South Northwest Highway, Park Ridge, Illinois 60068. Telephone: (312) 775-5344.

1—Type 2B67 Time-Base Unit. Price: \$150. Used 14 months. Contact: T. R. Evans or P. A. Leemakers, Department of Chemistry, Wesleyan University, Middletown, Connecticut 06457. Telephone: (203) 347-4421, ext. 379.

1—Type 504, SN 001387. Used only once; three years old. Contact: James E. Stewart, Electronics, 1308 William Flynn Highway, Glenshaw, Pennsylvania 15116. Telephone: 486-9797.

1—Type CA Plug-In Unit. Price: \$125. Contact: Mark Kramer Colortran In-

dustries, 1015 Chestnut Street, Burbank, California 91502. Telephone: (213) 843-1200.

5—Type 533, SN 1075, 001568, 002139, 002136, 002156. 1—Type 561, SN 00992. 1—Type 535A, SN 002184. 6—Type CA, SN 005528, 018803, 013-427, 009277, 013426, 023682. 1—Type 53/54E, SN 2220. 1—Type L SN 007-971. 3—Type H, SN 003170, 003169, 002970. 1—Type TU-2, SN 000791. 2—Type 63, SN 000342, 000341. 2—Type 67, SN 000570, 001118. 1—Type 180A Time-Mark Generator, SN 007-013. Contact: Victor Ferramosca, Computer Systems, Inc., 2042 Westmoreland Street, Richmond, Virginia 23230. Telephone: (703) 353-7856.

1—Type 130 LC Meter, SN 405, with S30 Delta Standard. Price: \$125. Contact: Mr. E. Silverman, Oak Park Tool & Die Company, 8726 Northend Avenue, Oak Park, Michigan 48237. Telephone: (313) 547-4688.

1—Type 524D, SN 750. Price: \$450. Contact: Ray Swalley, 5544 North 35th, Tacoma, Washington 98407. Telephone: (206) 752-3544.

1—Type 321, SN 001048 with P6022 Probe. Price: \$450. Contact: Miss Jensen, Electro-Autosizing Machine Corporation, 140 Woodland Avenue, Westwood, New Jersey. Telephone: (201) 664-5540.

1—Type 532, with CA, B, L, and 1L20 Plug-Ins. Price: \$2150 complete. All units perfect and guaranteed. Contact: G. Cecil Translab Inc., 4740 Federal Blvd., San Diego, California 92102. Telephone: (714) 263-2246.

1—Type 514, SN 1545. Contact: Steve Halmo, Nystrom Aviation, 1901 Em-

barcadero Rd., Palo Alto, California 94303. Telephone: (415) 327-7640, ext. 17.

1—Type 564, SN 2157. 1—Type 3A1, SN 1410. 1—Type 3B4, SN 140, 2—Type P6006. 1—Type P6028. Price: \$1450. All in good condition. Contact: James W. Browder, Ryan K. Aeronautical Co., San Diego, California. Telephone: (714) 296-6681, ext. 8247 or 8248.

1—Type 536, SN 260; 1—Type 53/54T. Price: \$600. 1—Type 502, SN 2139. Price: \$550. 1—Type 504, SN 908. Price: \$250. 1—Type 53/54E Plug-In. Price: \$75.00. Contact: Eric W. Vaughan, The Superior Electric Company, Bristol, Connecticut 06010. Telephone: (203) 582-9561.

1—Type 310, SN 4978. Contact: COMMSULT, Inc., 3355 Prairie, Boulder, Colorado. Telephone: 444-5900.

USED INSTRUMENTS WANTED

1—Type 585A/82/1A2/1A6. Contact: Mr. Ettinger, Mark Computer Systems, 40 South Mall, Plainview, New York 11803. Telephone: (516) 694-9655.

1—Type 575 Curve Tracer. Contact: Derrick Lindsay, 13 Beechwood Lane, Westport, Connecticut. Telephone: (203) 227-5957.

2—Type S Plug-In Units. In any condition. Contact: Murray Goldstein, Scientific Components, 350 Hurst St., Linden, New Jersey 07036. Telephone: (201) 925-4022.

1—Type 585. 1—Type 82. Contact: Donald A. Paris, 48 East Circle Drive, East Longmeadow, Massachusetts 01028.

Reading Capacitor Codes

There are a number of different color codes for capacitors. The following summary should help you save time in identifying most of the capacitors you encounter. Different marking schemes are used mainly because of the varying needs the different capacitor types fulfill. For instance, temperature coefficient is of minor importance in an electrolytic filter capacitor, but very important in ceramic trimmers for attenuator use. You never find temperature coefficient (T_c) on an electrolytic label, but ceramic trimmers always carry it.



I. CERAMIC DISC CAPACITORS

Often called "discaps" (that's the trademark of one manufacturer), ceramic disc capacitors are available in two categories: temperature compensating or class I, and "high-K" or class II. T_c types usually carry the capacitance in pF's directly. Tolerance may be shown in percent or by letter:

M	= $\pm 20\%$
K	= $\pm 10\%$
J	= $\pm 5\%$
G	= $\pm 2\%$
F	= $\pm 1\%$

Temperature coefficient is indicated by P100, which means $+100$ P/M/ $^{\circ}$ C, or N750 for -750 P/M/ $^{\circ}$ C, NPO for 0 P/M/ $^{\circ}$ C, N030 for -30 P/M/ $^{\circ}$ C, etc. All these T_c 's have a tolerance, too. NPO is usually ± 30 P/M/ $^{\circ}$ C, with looser tolerance on larger T_c 's. T_c tolerance is also looser on very low capacitance parts.

"High-K" types list capacitance the same way (or in μ F), and in addition sometimes use a multiplier scheme as follows: 102 for 1000 pF, 473 for 47,000 pF, etc. Capacitance tolerance is shown as above, with the addition of P for GMV ("guaranteed minimum value" or -0 , $+100\%$), and Z for -20 , $+80\%$. The temperature coefficient of these units is usually not linear, so only the maximum capacitance change due to temperature from the 25° C value is given. This is called the "temperature characteristic", a typical case being

"Z5U". This table explains the meaning of the more common temperature characteristic designations. Temperature range over which characteristic is effective:

Z5:	$+10^{\circ}$ C to $+85^{\circ}$ C
Y5:	-30° C to $+85^{\circ}$ C
X5:	-55° C to $+85^{\circ}$ C
W5:	-55° C to $+125^{\circ}$ C

Limits of capacitance change from the room temperature value:	D: $\pm 3.3\%$
	E: $\pm 4.7\%$
	F: $\pm 7.5\%$
	S: $\pm 22\%$
	U: $+22$, -56%
	V: $+22$, -82%

Thus "Z5U" means that temperature can cause the capacitance to increase a

maximum of 22%, or decrease a maximum of 56% from the room temperature value, within the limits of $+10^{\circ}$ C and $+85^{\circ}$ C.

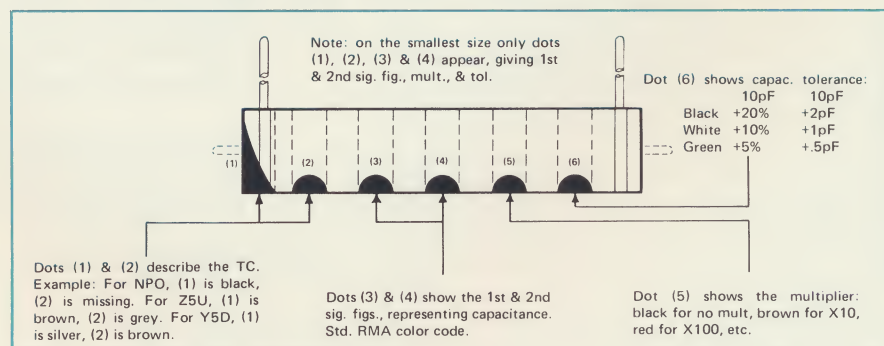
Whether voltage rating appears on a disc depends on the manufacturer's practice. Most do not include it on their "standard" voltage rating, which is 1000 V for Sprague and RMC, and 500 V for Erie. Other voltage ratings, however, are printed on the capacitor.

High-voltage ceramic discs and plates used at Tektronix are of class II dielectric material, and carry labels similar to the class II discs.

II. CERAMIC TUBULAR CAPACITORS

These units are usually white enamel coated and have parallel radial leads. "Dog bones" come in both class I and class II dielectrics and in several sizes, at least one being too small for a complete code of any kind. The code consists of color dots which show T_c , ca-

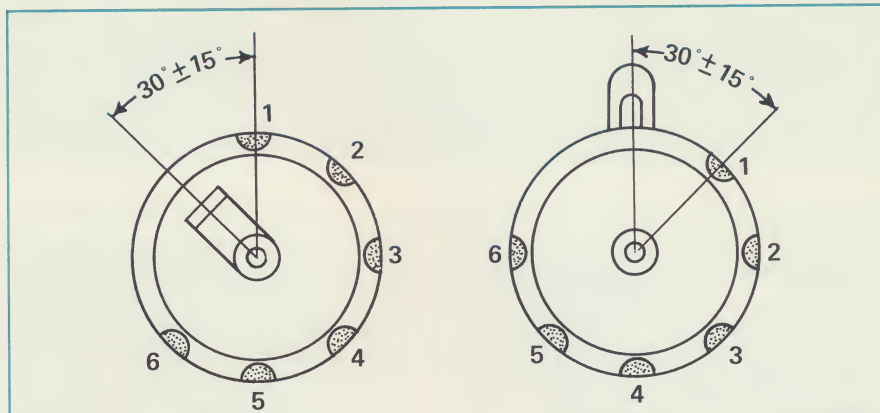
pacitance, and tolerance. The smallest style shows only capacitance and tolerance, and none can show the capacitance of a close-tolerance part to greater than two significant figures. The more common examples are illustrated below.



III. BUTTON MICA CAPACITORS

The most difficult aspect of understanding the code on these parts is "where do you begin?" The sketch shows that the first dot is keyed to a center terminal lug.

- | Dot | Meaning |
|-------------------------------|---|
| 1. Identifier: | Black, except omitted where capacitance must be specified to 3 significant figures. |
| 2. Capacitance: | 1st significant figure in pF. |
| 3. Capacitance: | 2nd significant figure in pF. |
| 4. Multiplier of Capacitance: | black = X1, brown = X10, red = X100, etc. |
| 5. Capacitance Tolerance: | black = $\pm 20\%$, silver = $\pm 10\%$, gold = $\pm 5\%$. |



6. "Characteristic": black (means a temperature coefficient falling somewhere between -20 and $+100/P/M/^{\circ}C$).

Note: The dots always read in a clockwise direction.

If the button has no center lug terminals, the manufacturer tries to put the dots more on one side than out on the very edge; thus the code can be seen from one side only.

IV. MOLDED MICA CAPACITORS

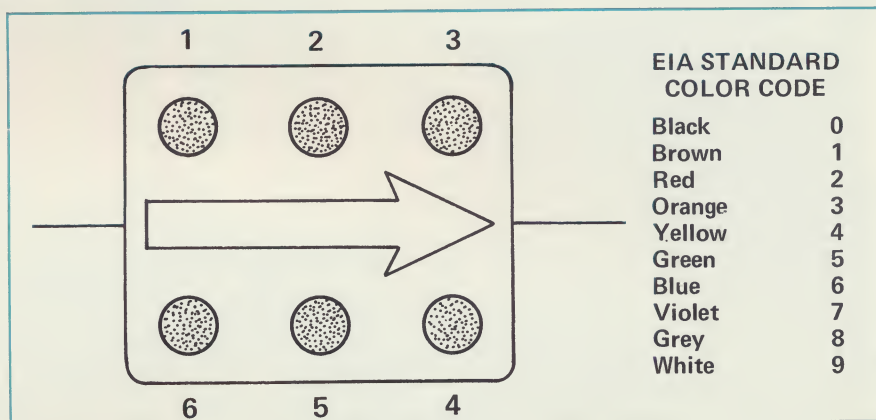
Color codes on this type vary, causing much confusion. There are two basically different code schemes, one being "OLD", the other one being the EIA/MIL scheme currently in use. The sketch shows the difference.

OLD

- | Dot | Meaning |
|-------------------------------|---|
| 1. Capacitance: | 1st significant figure in pF. |
| 2. Capacitance: | 2nd significant figure in pF. |
| 3. Capacitance: | 3rd significant figure in pF. |
| 4. Multiplier of capacitance. | |
| 5. Tolerance: | Black = $\pm 20\%$
Silver = $\pm 10\%$
Green = $\pm 5\%$
Brown = $\pm 1\%$ |
| 6. "Characteristic": | Brown = B
Yellow = E
Green = F |

EIA/MIL

- | Dot | Meaning |
|-------------------------------|--|
| 1. Identifier: | White if per commercial specification, black if per mil specification. |
| 2. Capacitance: | 1st significant figure in pF. |
| 3. Capacitance: | 2nd significant figure in pF. |
| 4. Multiplier of capacitance. | |
| 5. Tolerance: | same as "OLD". |
| 6. "Characteristic": | same as "OLD". |
- Note: "Characteristic" in mica capacitors refers to the temperature coefficient and capacitance drift.



Char.	T _c (P/M/°C)	Drift
B	±500	±3% +1 pF
C	±200	±(0.5% +0.5 pF)
D	±100	±(0.3% +0.1 pF)
E	-20 to +100	±(0.1% +0.1 pF)
F	0 to +70	±(0.05% +0.1 pF)

V. DIPPED MICA CAPACITORS

These carry a printed label much like that on ceramic discs. They may include the characteristic letter explained in the preceding table at left.

VI. PAPER & FILM CAPACITORS

Aluminum and Tantalum Electrolytic Capacitors: In almost all cases they

carry printed or stamped labels consisting of capacitance, tolerance, and voltage rating. Other characteristics are either unimportant or are reasonably consistent in all capacitors of the same kind.

VII. CERAMIC TRIMMERS

The printed-on labels usually show capacitance range and temperature characteristic. TC reads the same as on ceramic discs. The tolerance on TC of ceramic trimmer rotors is much looser than on fixed capacitors, for mechanical reasons.

VIII. AIR TRIMMERS

The same principle applies as in the case of paper and film capacitors. Only capacitance range need be indicated as TC is essentially uniform in this type.



SERVICE SCOPE

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Editor: R. Kehrli

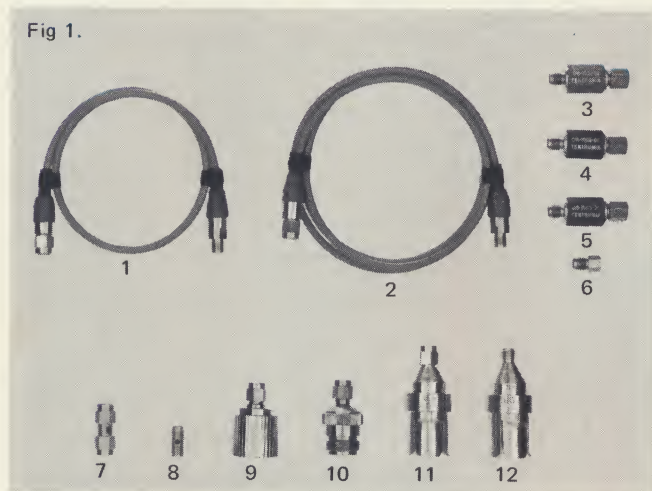
Artist: J. Gorman

This issue of SERVICE SCOPE discusses some of the state-of-the-art developments in sampling technology. Since the development of sampling by Janssen and Michels in 1950, Tektronix engineers have made a number of significant contributions to sampling technology. Listed below are some of the more important developments and the year in which they occurred.

- 1960 Plug-in sampling unit converts conventional oscilloscope to sampling oscilloscope at modest cost.
- 1962 High-quality delay lines allow internal triggering and the observation of signal leading edges. Miniature low capacitance, passive probes developed.
- 1962 Digital readout introduced.
- 1963 100-ps sampling introduced.
- 1964 Low-cost, high-resolution storage combined with sampling.
- 1965 Miniature high-impedance sampling probes introduced.
- 1966 Wide-range sampling time base introduced, 10 ps/cm to 5 s/cm.
- 1967 Random sampling eliminates need for signal delay lines. Allows viewing of up to 5 cm before trigger.
- 1968 New sampling concept developed. 6 plug-in heads introduced. 25-ps sampling with 35-ps TDR. Programmable sampling units, digital delay, and 3 mm connectors.
- 1969 MORE TO COME!

SOMETHING NEW IN OSCILLOSCOPE CONNECTORS

Fig 1.



NO	ITEM	PN
1	Cable, 2 ns	015-1005-00
2	Cable, 5 ns	015-1006-00
3	Attenuator, 2X	015-1001-00
4	Attenuator, 5X	015-1002-00
5	Attenuator, 10X	015-1003-00
6	Termination, 50 Ω	015-1004-00
7	Adapter, M to M	015-1011-00
8	Adapter, F to F	015-1012-00
9	Adapter, M to 7 mm	015-1010-00
10	Adapter, M to N(F)	015-1009-00
11	Adapter, M to GR	015-1007-00
12	Adapter, F to GR	015-1008-00

A 3-mm (mates with OSM®*) line of connectors is currently stocked by Tektronix. When development of the 50-ps (7-GHz) Type S-2 Sampling Head was completed, studies were undertaken to determine the best connector for higher-frequency sampling oscilloscope designs. As a result, Tektronix has standardized on the 3-mm miniature connector line for higher-frequency developments.

This line of connectors offers the following advantages to the customer: (1) Operation at all frequencies up to 26 GHz. Since the 25-ps S-4 Sampling Head represents 14-GHz response, there is sufficient additional performance so the connector does not present a design limitation. (2) Availability of a full range of adapters and accessories from a number of manufacturers at competitive prices. Adapters are commercially available to adapt to Type N, TNC, BNC, GR, ARC, and OSSM. (3) It is a high-reliability connector because of the following considerations: (a) It is self cleaning, thus it is difficult for gradual signal degradation to occur. At the same time, a time-consuming cleaning process is not required. (b) There are fewer moving parts, so the surface-to-surface contact is better than other connectors available. (4) The VSWR of the 3-mm line is quite good, although not as good as some of the more precise, larger diameter lines. The high-speed sampling gate inherently produces discontinuities that negates much of the value of an expensive, high-precision connector. Therefore, the less expensive, medium precision 3-mm connector seems a good choice. In addition, the VSWR can be improved by inserting a high-quality attenuator, with very little sacrifice to the user. (5) Minimum front-panel space is required.

These considerations represent an excellent value connector for the customer. Fig 1 shows the 3-mm accessories currently being stocked by Tektronix.